Object-space Morphing

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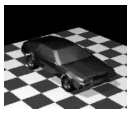
What is Metamorphosis

- Metamorphosis (or Morphing) is a transformation that given a source and target shapes, gradually and continuously, deforming the source shape into the target shape, while producing the in-between shapes.

Applications

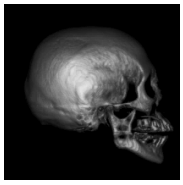
- These techniques are now very popular in the entertainment industry, and are used in biomedical applications as well.



Classification by the Representation

- Discrete representations
  - Images (raster graphics)
  - Volumes (voxel-based)
- Boundary representation
  - Explicit (Splines, polygons, polyhedra, etc.)
  - Implicit

Morphing volumes



Morphing parametric surfaces

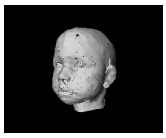
Good and bad morphs

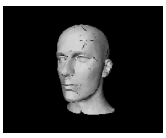
- An unacceptable morph sequence

- An acceptable morph sequence

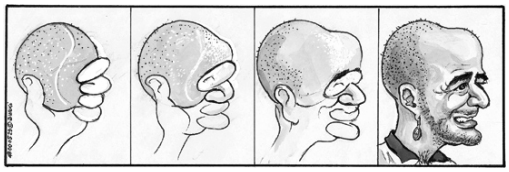
Naturalness

- A good morph should be perceptually "natural"
  - Corresponding features of the source and target objects should be morphed one into another (e.g. nose to nose, ear to ear, etc.)





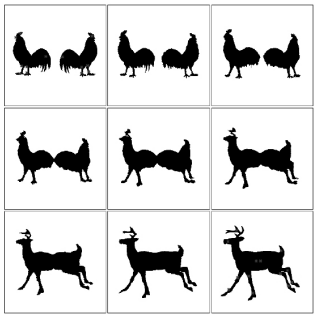
Is this a Good Morph?



Morphing

- Requires solving two (usually) distinct problems
  - Correspondence problem
    - Defines the hard constraints in the morph
    - Point-to-point constraints
  - Path problem
    - Defines how the point travels to its destination

Point-to-point Correspondence

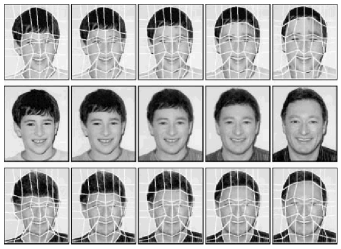


Naive image morphing

- Linearly interpolate between colors of corresponding pixels
  - That is, solve only the path problem, without solving the correspondence problem

A better solution

- Establish correspondence between image features
- Warp between corresponding features



A combination

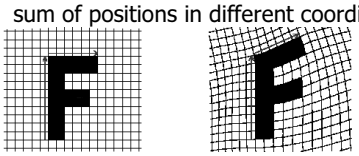
- A morph is usually a combination of two processes
  - Warping - defining the geometric transformation that distorts the source and the target objects
  - Blending - merging the two warped objects into one by interpolating the values (e.g. colors) of corresponding elements of the two models.

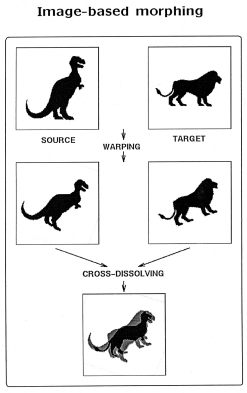
Image Morphing

- Vector-based Morphing
  - Identify corresponding features with oriented line segments

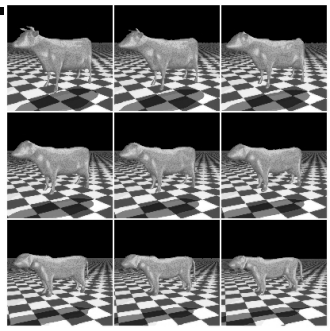
Image Morphing

- Field Morphing
  - Lines define local coordinate spaces
  - Coordinate spaces are linearly transformed
  - Pixel position is determined by a weighted sum of positions in different coordinate

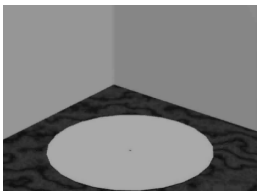




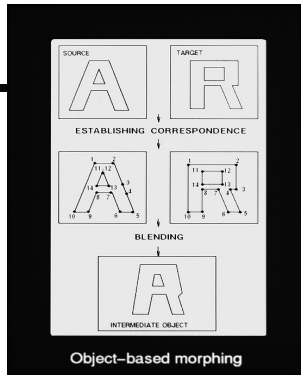
Object-space Morphing



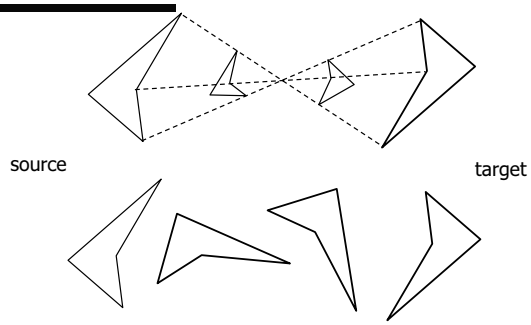
Object-space Morphing



(C) Gershon Elber, Technion



The Vertex path



The path problem

- Naive linear interpolation between corresponding vertices may cause self-intersections and unpleasant deformations

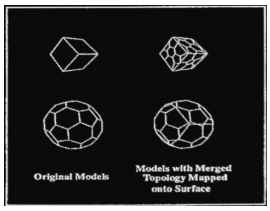
The rest of the tutorial:

- DFI morphing: Daniel Cohen-Or
- Polygon Morphing: Vladlen Koltun
- break
- Mesh Morphing: Marc Alexa

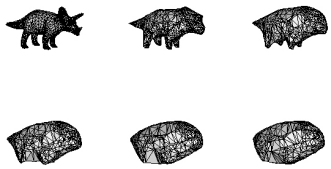
Acknowledgement: Thanks to Takashi Kanai, George Wolberg and Gershon Elber for many of the images used in this slide.

The correspondence problem

- Kent et al (SIGGRAPH'92) solve the vertex correspondence problem for 3D polyhedra by merging their topological structure



The 3D polygon evolution process



The path problem

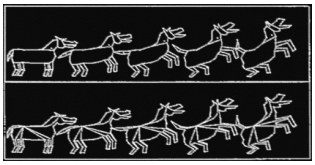
- Sederberg et al (SIGGRAPH'93) presented an approach that interpolates edge angles and lengths, rather than vertex positions

Linear interpolation causes artifacts (e.g. compressed neck)

A more natural result, produced by the algorithm of Sederberg et al.

The path problem

- Shapira and Rappoport (IEEE CG&A '95) use a connecting skeleton to define the vertex path, thus achieving control on the interior of the shape as well as its boundary



Three-Dimensional Distance Field Metamorphosis

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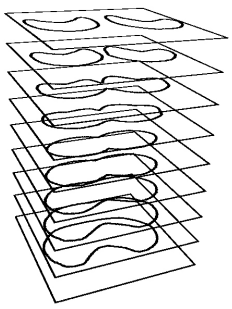
The reconstruction problem

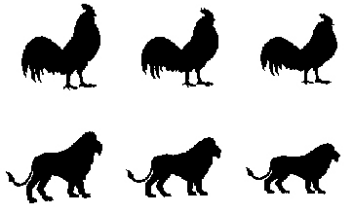


Gray-level interpolation

- Results of the gray-level interpolation before thresholding

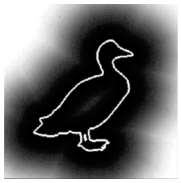
Gray-level interpolation

- Results of the gray-level interpolation after thresholding

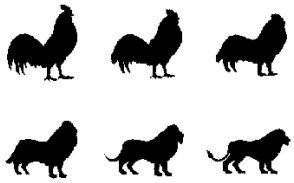


The Distance Field Interpolation

- The Distance Field of a contour image. The distances appear in absolute values.

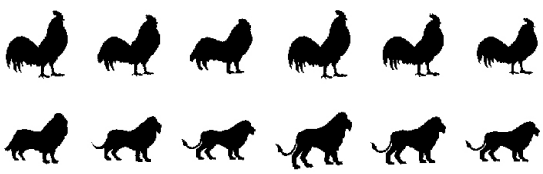


Distance Field Interpolation (DFI)



Smoother Transition

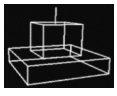
Distance Field Interpolation Gray Level Interpolation



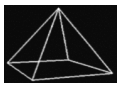
Two types of interpolation

- Three equally-spaced cross-sections

- The reconstruction results



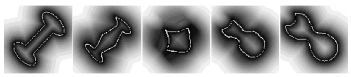
Gray-level interpolation



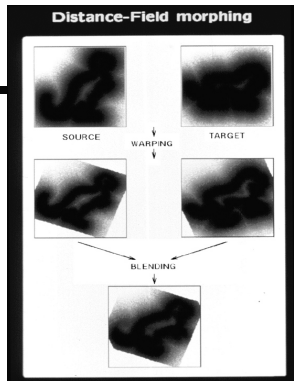
Distance field interpolation

Comparing the morphing results using the DFI method

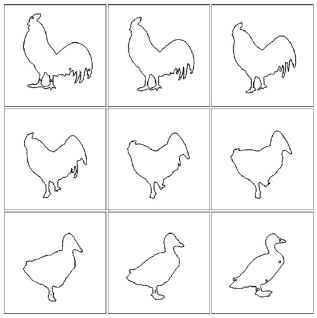
- Without any warp



- Using a proper warp

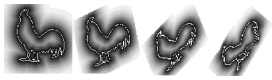


A Rooster morphs into a duck

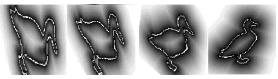


Warp-Guided DFI

- The source Distance Field warped towards the target



- The target Distance Field warped towards the source



- The intermediate interpolated Distance Field

The rigid-elastic decomposition

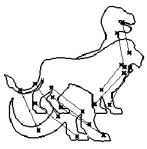
The Warp transformation W is decomposed into a Rigid part and an Elastic part, which are separately interpolated.

The Rigid part is used to rotate and translate the source object to a matching general position of the target object, while the fine feature of the object are evolved by the elastic part.

$$W(x) = E(R(x)+c)$$

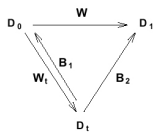
The rigid part minimizes the work of the elastic part

The elastic part with the rigid transformation



The elastic part without the rigid transformation

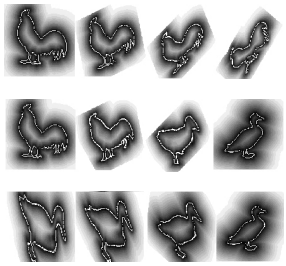
The Discrete Morphing Procedure



- The distance value $D_t(v)$, assigned to a voxel $v \in X$ is calculated by

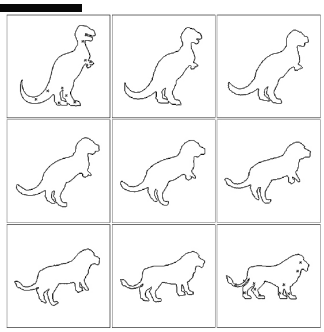
$$D_t(v) = (1-t)D_0(B_1(v)) + tD_1(B_2(v))$$

Source warps over time towards target

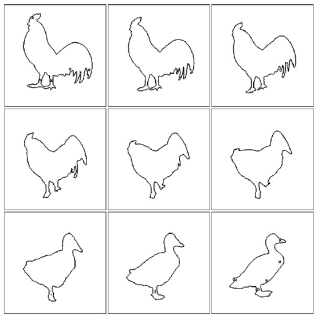


Target warps over time towards source

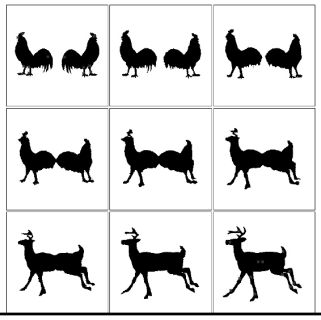
2D Contour Blending



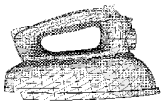
A Rooster morphs into a duck



Blending two Objects into One



Surface reconstruction results

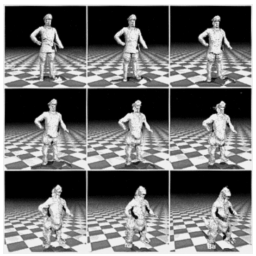


The original
iron
(2600 triangles)

The model voxelized
in a resolution of 100^3
(42482 triangles)

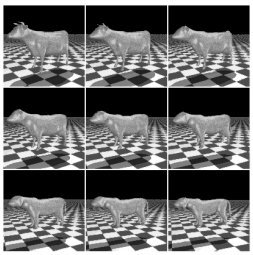
Results

- A soldier turns into a T-Rex



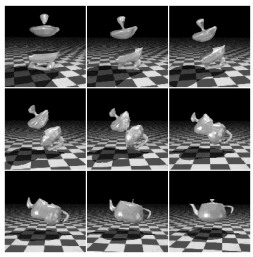
Results

- A cow turns into a tiger



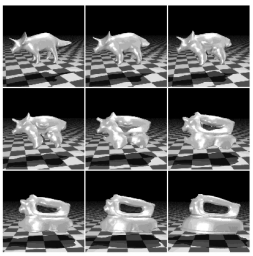
Results

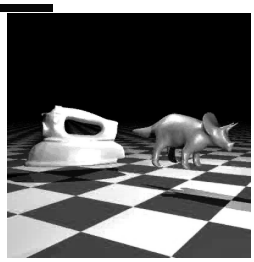
- A mushroom and an iron turn into a teapot



Results

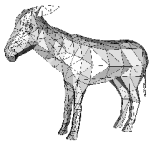
- A dinosaur turns into an iron



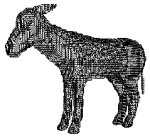


Thank you

Surface reconstruction results

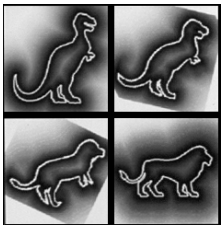


The original donkey (874 triangles)



The model voxelized at a resolution of 100^3 (26764 triangles)

Distance Field Interpolation

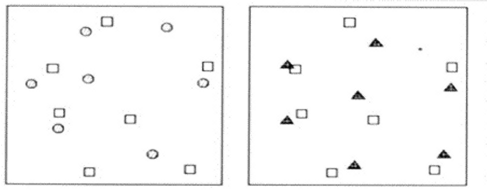


The Rigid Transformation in R^3

- Let $\{s_i\}_{i=1}^N$ and $\{t_i\}_{i=1}^N$ be the source and target sets of anchor points, respectively.
- The rigid transformation is defined by the rotation R and the translation c that minimize the expression

$$Q = \sum_{i=1}^{N} \|Rs_i + c - t_i\|^2$$

The Rigid Transformation in R^3



○ – The source anchor points
□ – The target anchor points
▲ – The source points after applying rigid transformation